Static and dynamic behavior of soft clay soils stabilized with virgin fibers

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1. Background

When expansive clay soils are subjected to moisture, they may swell and subsequently their strength decreases. Therefore, presence of such clay soils with possibility of volume change due to environmental effects is known as one of the common problems in geotechnical engineering practice. Nowadays, improvement methods are widely used around the world. Application of these methods in construction improves the geotechnical parameters of the soil, reduces the incurred costs, shortens the construction time, and increases durability of the construction materials. In these methods, the reinforcing or stabilising type of materials are used to strengthen the soil and to improve the engineering characteristics and mechanical properties of the soil, namely shear strength parameters, stiffness, ductility, and load bearing capacity, using scientific principles and new technologies.

With advances in soil improvement techniques, there are multiple methods of soil reinforcement and stabilization choices depending on the type of the soil and project condition including mechanical, chemical, physical, biological (growing plant), and electrical techniques. Soil reinforcement technique is considered as a physical method that was first proposed by Vidal et al. (1966) in France. One of the soil reinforcement methods is mixing it with short fibres and filaments. Combination of these reinforcing elements with soil forms a composite material that involvement of reinforcement elements with soil grains improves soil strength and ductility. Gary and al-Rifai were among the first researchers who examined the reinforced soil using triaxial compression tests on fibre reinforced sand, and they showed that the increase in soil strength is proportional to the amount of reinforcing materials. The findings of Ranjan et al (1996). on samples reinforced with fibres using triaxial tests, studies carried out by Wang and Frost using uniaxial and triaxial tests on mechanical behavior of reinforced argillaceous sands, as well as the triaxial direct shear tests conducted by Santoni and Bistro on reinforced sand soils. All studies indicate the fact that the reinforced samples have more ductility than non-reinforced ones, and the shear strength increases by increasing the amount fibres in the soil. Michalowski and Zhao (1996) proposed a measure for breaking of sand reinforced with steel and polyamide fibres based on a comprehensive experimental and theoretical research. According to their study, reinforcement increases the compressive and shear strength of the soil, improves the response of soil mass to dynamic loads, increases dynamic shear moduluse of the soil, reduces liquefaction potential, and increases the soil ductility [1]. Soleimani et al. (2016) investigated the dynamic behavior of the sand containing fibre under triaxial cyclic loading. Their study indicated that adding fibre improves shear strength and the maximum axial strain of the soil [2].

Soil reinforcing materials include metal, polymer, and plant components. The compressive stresses applied on the composite material cause mobilization of shear stresses at the interface of soil and reinforcing element by deforming the elements in the composite material. Reaction of these stresses creates tension forces in the reinforcing elements, in which the friction between soil and reinforcing element has a fundamental role. Soil reinforcing elements can be divided into two categories. These two categories are different in terms of implementation method and -mechanism: a) continuous elements, b) short fibres and filaments.

Metal reinforcing materials and geosynthetics (e.g., geotextiles, geogrids, geomembranes, etc.). Fibres and filaments include natural fibres, synthetic fibres, and/or the filaments resulted from crushing or cutting natural materials (e.g., plant components), synthetic materials (e.g., different polymers), or recycled materials (e.g., garbage bags, bottles made of PET, textile waste, or carpet waste, etc.). Fibres easily mix with soil and the resulted composite material is called fibre reinforced soil with random distribution of fibres. Since the reinforcement elements mix with the soil in a random distribution, there is the possibility of presence of fibres in any location and direction within the reinforced soil. Therefore, unlike the continuous elements positioned in a specific direction and in certain locations among soil layers, fibres with random distribution improve the soil properties in all directions. Therefore, using fibres creates a homogeneous material and eliminates planes of weakness. Studies show that stress-strain characteristic of fibre reinforced soils is a function fibres content, fibre aspect ratio, and fibre tensile strength and elongation [2, 3].

2. Aims

The purpose of this study is to investigate the static and dynamic behaviour of clay soil reinforced with short fibres. The effect of different fibre percentages and sizes on the static and dynamic behaviour of clay soils are examined in this study. Moreover, we aim to study the effect of presence of some percentages of sand and silt on the behavior of clays samples reinforced by fibres.

This study uses triaxial cyclic (dynamic) tests to examine stress direction and loading conditions on the soil behavior and strength, and to determine the soil dynamic parameters, namely dynamic shear modulus and damping ratio, as well as numerical modeling of the samples.

3. Research Methodology

In the present study, the uniaxial strength of clay soil, sandy clay soil, and silty clay soil reinforced with fibres with different lengths are examined and compared with each other. Sand and silt are added to clay soil in order to evaluate their effect on the strength parameters of stabilized clay soil. Furthermore, sandy clay is a problematic soil, in which evaluation of the stabilizing materials is of great importance. Laboratory samples are prepared under optimum moisture and maximum unit weight of clay soil or sandy clay with different percentages of fibre according to Australian standard, then the dynamic parameters are examined by triaxial dynamic tests.

Sensitivity to these two factors is investigated by changing the moisture content and weight percent of sand and silt in the samples. To examine dynamic behaviour of the samples, parameters such as shear moduluse and damping ratio of the soil can be obtained by applying cyclic loads at different frequencies and recording the stress and strain. This study aims to examine the effect of sample reinforcement with different weight percentages of fibre on dynamic behaviour of the samples, namely damping coefficient and shear moduluse, by performing cyclic tests.

4. Significance

Nowadays, using different methods for soil reinforcement and improving strength properties of soil has found a wide application in civil projects. One of these methods is using synthetic fibres. This issue is of great importance in studying and investigating subsidence of fine-grained soil, and subsidence of the foundation of most civil structures [4].

Soil stabilization is referred to all operations performed to improve geotechnical properties of the soil with a specific purpose. These properties include strength, ductility, permeability, durability, fatigue, etc.. Depending on the project and its objective, the geotechnical properties to be optimized are identified, according to which the stabilization type is determined. General results of improving inferior soil, which enhances soil behavior, are:

- Improving shear strength of the soil and increasing its l loading capacity as a result
- Reducing soil subsidence, increasing ductility, and decreasing the rigidity of soil structures
- Reducing the cost of soil structures and speeding up the operations
- Stability against climatic factors, such as repeated cycles of freezing and melting ice
- Reducing the thickness of load bearing layers
- Increasing safety factor against sliding roofs and dams

5. References

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